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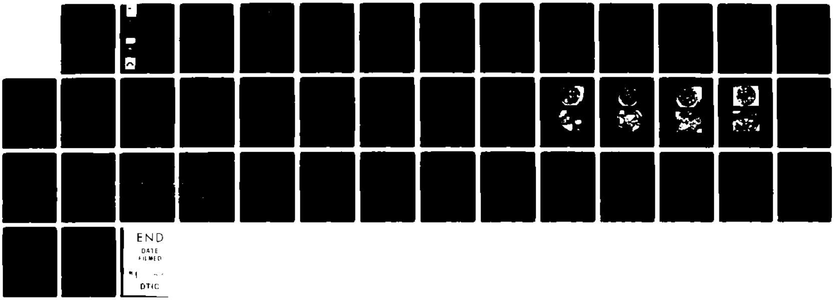

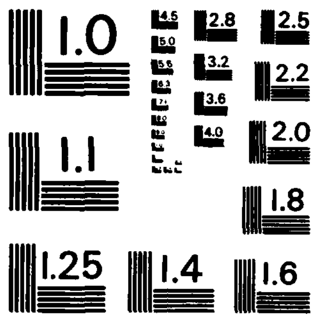

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EVALUATION OF CONCRETE CORES CARUTHERSVILLE FLOODWALL

by

G. Sam Wong

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US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

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Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Core drilling followed by laboratory testing provided petrographic and physical data on the concrete from the Caruthersville Floodwall. The floodwall consisted of an old wall constructed before 1932 and a newer wall constructed in 1932. Concrete cores representing the old and newer concrete from various locations in the structure were tested to determine ultrasonic pulse velocity, compressive strength, and density.

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20. ABSTRACT (Continued)

The petrographic examination indicated the presence of alkali-silica reaction product as isolated fillings in voids, coating some aggregate particles, and in some instances as coatings of cracked surfaces. No other deleterious chemical reaction product was identified in the concrete.

The compressional wave velocities had an average value over 15,000 fps for the new concrete and over 14,500 fps for the old concrete. The average compressive strengths were 7630 psi for the new concrete and 3790 psi for the old concrete. One specimen of old concrete tested had a low ultrasonic pulse velocity of 10,970 fps, which correlated to a low compressive strength of 2,020 psi. Concrete densities were all consistently near 150 lb/cu ft.

In general, the concrete appeared to be in acceptable condition. Only minor repairs involving monolith joints, isolated vertical cracks within monoliths, and areas of localized deteriorated concrete were recommended.

PREFACE

Tests and petrographic examination of concrete cores from the Caruthersville Floodwall located in Caruthersville, Missouri, were conducted for the U. S. Army Engineer District, Memphis. The work was authorized by DA Form 2544, No. LMMCO-0-83-1.

Drilling was conducted by personnel of the Geotechnical Laboratory (GL) of the U. S. Army Engineer Waterways Experiment Station (WES) during the period 29 March 1983 to 4 April 1983 under the direction of Mr. M. A. Vispi. Laboratory tests were performed at the Structures Laboratory (SL) of WES during the period April 1983 through June 1983 under the direction of Messrs. Bryant Mather, Chief, SL; J. M. Scanlon, Chief, Concrete Technology Division, SL; and R. L. Stowe, Acting Chief, Materials and Concrete Analysis Group, SL. Mr. G. S. Wong was Project Leader and was assisted in performing laboratory work at the SL by Messrs. T. G. Ray, A. M. Alexander, and M. K. Lloyd. Mr. J. E. McDonald examined the data and made the repair recommendations. Mr. Wong prepared the report.

The Commander and Director of WES during the conduct of this study and preparation of this report was COL Tilford C. Creel, CE. The Technical Director was Mr. Fred R. Brown.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
inches	0.0254	metres
feet	0.3048	metres
pounds (force)	4.44822	newtons
pounds (mass)	0.4535924	kilograms
pounds (force) per square inch (psi)	0.006894757	megapascals
pounds (mass) per cubic inch	27,679.90	kilograms per cubic metre
feet per second	0.3048	metres per second

EVALUATION OF CONCRETE CORES, CARUTHERSVILLE FLOODWALL

PART I: INTRODUCTION

Background

1. The Caruthersville Floodwall was authorized by the Flood Control Act and approved 15 May 1928 with subsequent amendments. It was completed in 1932 by Volz Construction Company. The construction effort included raising an existing wall and construction of a new wall to a project grade of 286.0 ft MGL (MGL-19 ft is equal to NGVD).* The project consists of 2990 linear ft of concrete wall.

2. The floodwall is operated and maintained by the St. Francis Levee District of Missouri. The Levee District requested that the U. S. Army Engineer District, Memphis determine the condition of the concrete in the floodwall and recommend what maintenance or repair is needed. The District is involved with the evaluation of cracks in the structure and the determination of possible repair measures to be implemented.

Authority

3. The Memphis District requested that the U. S. Army Engineer Waterways Experiment Station (WES) provide manpower, equipment, and expertise in evaluating the concrete in the Caruthersville Floodwall. The work was to begin on 21 March 1983 and a letter report with recommendations for repair of the floodwall was to be submitted by 15 June 1983.

4. Funding was made available under the Mississippi River Levees Maintenance Project. Project funds were transferred to WES by DA Form 2544, order No. LMMCO-0-83-1, issued 9 March 1983 by the Memphis District. The project was initiated based on a brief inspection in February 1983 by WES.[1]

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

MGL = Mean Gulf Level; NGVD = National Geodetic Vertical Datum.

Floodwall Description[2]

5. The floodwall is located at Caruthersville, Missouri, along the right bank of the Mississippi River from levee station 27/47 to 28/25. The following tabulation presents pertinent information on the floodwall:

Project Flood	
Station 27/47	283.8 ft NGVD
Station 28/25	283.6 ft NGVD
Maximum stage of record	
Ft NGVD	281.49
Ft MGL	281.68
Project Grade	
Ft NGVD	285.81
Ft MGL	286.00
Average Freeboard (Above Project Grade)	2.0
Length of Protection	
Concrete Floodwall (lin ft)	2990.0±
Construction Date	1932
Zero Gage (ft NGVD)	235.5

Design of Floodwall

6. A review of the design criteria for the floodwall is included below:

a. Design assumptions.

(1) Working stress

f'_c (compressive strength)	3,000 psi
fc (compressive stress)	1,000.0 psi
fs (stress in steel)	18,000.0 psi
v (shear stress)	60.0 psi
u (bond stress)	225.0 psi

(2) Densities

Concrete	150.0 pcf
Saturated earth	120.0 pcf
Dry earth	100.0 pcf
Water	62.5 pcf

(3) Equivalent fluid pressures

Water	62.5 psf
Dry earth	33.0 psf
Moist earth	50.0 psf
Saturated earth	100.0 psf

b. Original design. The existing floodwall was raised and the new wall was constructed to a project grade at 285.81 ft NGVD in 1932. The following design requirements were used:

(1) Concrete levee wall was designed as a gravity section.

(2) The force resultant was restricted to the middle third base when water was 1 ft below top of wall.

(3) Factor of safety against sliding (sheet piling neglected) of not less than 1.

(4) Length of sheet piling sufficient to provide seepage travel equivalent to that provided by base of earth levee.

PART II: PROCEDURES

Cores

7. A total of twelve 6-in.-diameter concrete cores were taken from the Caruthersville Floodwall. The coring was accomplished by a WES drill crew. The coring operation began 29 March 1983 and was completed 4 April 1983. The drill crew returned to WES with the cores on 7 April 1983. Three vertical and two horizontal cores were drilled from the old concrete (concrete placed prior to 1932 construction). One slant core and six horizontal cores were drilled into new concrete (1932 construction). The identification and locations of the cores are presented in Table 1. The station numbers are river miles established by measuring from known stations on the structure such as the openings in the floodwall (Plate 1). The monolith numbers are references painted on the floodwall sections which are also referred to in portions of the Periodic Inspection Report[2] by the Memphis District.

8. Five types of gravity walls are represented by the 2990 lin ft of concrete floodwall. Nearly 2000 lin ft of concrete incorporate an old wall, Sections A and B (Figure 1), while the remaining wall sections are monolithic, Sections C, D, and E (Figure 2). Two cores were drilled from the old concrete in Section A and three from Section B. Two cores were drilled from the new concrete from Section A, three from Section B, and one each from Sections C and D. No concrete was taken to represent concrete from Section Type E because of the limited amount of concrete represented by this type of section.

9. The holes made into the sections of the floodwall during the coring operation were filled at the completion of the drilling operation. The vertical and slant holes were filled with 4000-psi concrete purchased from a local ready-mix distributor. The horizontal holes were plugged using a very low water/cement ratio sackcrete mixture which was rodded into the hole. The surfaces of the holes were finished using a mortar mixture.

Examination and Testing

Petrographic examination

10. All of the cores taken from the floodwall were examined before they were tested. Different concrete types were identified during this preliminary examination CRD-C 57-78[3] (ASTM C 856-77). Representative samples of the different types were later examined in more detail.

11. Pieces of core were broken to allow examination of freshly broken surfaces with a stereomicroscope. Cores were sawed and selected surfaces were ground smooth. These surfaces were examined using a stereomicroscope and photographs were made to illustrate the different concretes present in the structure.

12. A polarizing microscope was used to aid in the identification of concrete constituents and deleterious reaction products. Some alkali-silica gel was extracted from the concrete and examined as an immersion mount in an oil having an index of refraction of 1.490.

Ultrasonic pulse velocity

13. This was measured only as the compressional wave (p) CRD-C 51-72[3] (ASTM C 597-71). The p-wave transducers are coupled to the ends of the concrete specimen with an oil or a grease. A repetitive pulse from the seismic timer is sent through a cable to the transmitting transducer and the resulting ultrasonic signal propagates through the specimen at a velocity depending upon the material and its condition.

14. The time of travel through the specimen is the recorded time less the transducer zero time. The compressional wave velocity is calculated as follows:

$$Vp = d/t$$

where d is the length of specimen and t is the travel time

Unconfined compression

15. The unconfined compressive strength of the concrete was determined according to CRD-C 14-80[3] (ASTM C 39-80), "Compressive Strengths of Cylindrical Concrete Specimens." The specimens were sawed to a nominal 12-in. length and then capped with a high-strength sulfur-based capping compound according to CRD-C 29-78[3] (ASTM C 617-76).

16. The concrete structure in question does not generally experience saturation due to inundation; therefore, the specimens were not saturated by inundation prior to testing to better simulate field conditions. The cores were kept in a fog room for 5 days prior to testing.

17. Compressive strengths of the specimens were calculated by dividing the maximum load carried during the test of the specimen by the average cross-sectional area at midheight. The results were expressed to the nearest 10 psi.

Density

18. Coal particles in the concrete were thought to possibly have influenced the quality of the concrete and to have caused the concrete to have a significantly lower density than desired. The density of the concrete was measured with guidance from CRD-C 23-81a[3] (ASTM C 642-81), "Specific Gravity, Absorption, and Voids in Hardened Concrete." The bulk specific gravity was determined using a saturated surface dry weight measured after 24 hr immersion in water. The bulk specific gravity was calculated as follows:

$$\text{Bulk specific gravity} = \frac{B}{B - C}$$

B = weight of saturated surface dry test sample in air

C = weight of saturated test sample in water

The densities were calculated by multiplying the bulk specific gravity by 62.27 lb/cu ft.

PART III: RESULTS

19. The new concrete was generally uniform throughout the structure. It is competent and intact and does not show any signs of deterioration other than some normal surface weathering, which is very moderate. There are isolated longitudinal and vertical cracks which will be discussed in more detail later in this report. The new concrete is composed of 1-1/2-in. maximum size natural siliceous gravel and sand. Photographs 1a and 1b show a typical example of the new concrete. The concrete is well consolidated but tends to be oversanded with few intermediate size aggregate particles. Plates 2 through 13 describe the composition and condition of all 12 cores.

20. The old concrete tended to be more variable. Its composition ranged from 3/4-in. maximum size crushed limestone coarse aggregate to a totally siliceous aggregate concrete, as illustrated in Photographs 2a, 2b, 3a, 3b, 4a, and 4b. The physical condition of the old concrete also changed within a boring as well as between borings. Some of this concrete was severely honeycombed, contained cold joints and incipient fractures.

21. All of the siliceous coarse aggregate was composed of chert, quartz, sandstone, coarse-grained igneous rock particles, and some gneissic particles. The limestone was gray fine-grained crushed rock. Alkali-silica gel was found as a reaction product in both the old and the new concrete and in the concrete composed of only siliceous aggregate as well as in concrete having limestone coarse aggregate.

22. Sample MEM-5 CON-10 was taken from monolith No. 60 which was described as containing severe cracking. The core taken adjacent to the cracked area was intact and only indicated minor amounts of alkali-silica reaction gel. The reaction product was associated with a strained quartz particle showing undulatory extinction. Alkali-silica reaction gel was also present in samples MEM-5 CON-2, 6, and 7. MEM-5 CON-7 contained the most significant amount with the gel saturating the cement paste. The paste was very light gray (N8)[4] to light gray (N7)[4] in color. Other paste colors tended to be light gray (N7)[4] to medium gray (N6).[4]

23. In the new concrete, cracking normal to the formed concrete surface was minor. Usually, this type of cracking penetrated the concrete to depths less than 0.2 ft while many of the hairline cracks did not have any significant penetration into the concrete. Cracks such as those found in MEM-5 CON-10 and 11 did not show any active deleterious chemical reaction. The cracks are open to water movement and thus are generally stained.

24. The concrete of MEM-5 CON-4 showed incipient cracks developed parallel to the surface to a depth of 1.2 ft. This core was from the concrete adjacent to what was visually the most deteriorated concrete (monolith No. 43).[2] The concrete from MEM-5 CON-7 also showed incipient cracking in the interior concrete to about 0.7-ft depth while MEM-5 CON-8 contained isolated incipient cracking to a 3-ft depth.

25. Core MEM-5 CON-6 was taken to examine a major crack in the concrete. This was a vertical crack penetrating the entire thickness of the structure. The crack surfaces were stained by percolating water. It propagated through aggregate as well as around aggregate. A 1/2-in. rebar tied the cracked pieces together. There was no apparent deleterious reaction product in the crack. Some alkali-silica gel was observed in the paste adjacent to the crack.

26. Coal particles were found in most of the concrete core. Most that were observed tended to be small (less than 3/8 in. in size) and tended also to be infrequent in occurrence. There are only occasional larger pieces of coal present in the concrete cores that were taken.

27. The cores intersected numerous pieces of steel (Plates 2 through 13). All of the steel pieces were in good condition showing only a minimum amount of rusting. The pieces of steel were firmly fixed in the concrete except in cores MEM-5 CON-2 and 8 where there was some honeycombing around them. Both of the above cores were believed to contain tie bars grouted into the old concrete to connect the old to the new concrete. Sample MEM-5 CON-4 also contained a piece of steel believed to have been installed to tie the old concrete to the new; this piece is intact and in good condition but is much deeper in the section (about 6 ft).

28. The compressional wave velocity measurements, compressive strength determinations, and unit weight measurements were made using the same 14 samples with 7 samples representing the old concrete and 7 samples representing the new concrete. All physical test results are presented in Tables 2 and 3 for the old and new concrete, respectively.

29. The compressional wave velocities for the old concrete ranged from 10,970 fps to 15,366 fps with an average of 14,568 fps. Most readings were near or above 15,000 fps. The only exception was sample MEM-5 CON-8 at 0.0 to 1.0 ft, which read 10,970 fps. This correlated with low compressive strength and low unit weight of this specimen (Table 2).

30. All compressive strengths of the old concrete were above 3000 psi except for sample MEM-5 CON-8 (2020 psi) mentioned above. The average strength of the old concrete was 3790 psi (Table 2).

31. The average unit weight of the old concrete was 149.3 lb/cu ft. The lowest density concrete was again MEM-5 CON-8 (145.1 lb/cu ft) (Table 2).

32. The compressional wave velocities of the new concrete averaged 15,276 fps with a range from 14,926 fps to 15,950 fps. The compressive strengths averaged 7,630 psi with a range of 6,140 psi to 10,680 psi (Table 3).

33. The density measurements of the new concrete were slightly lower overall than those of the old concrete with an average of 148.5 lb/cu ft. The concrete densities ranged from 146.3 to 150.3 lb/cu ft (Table 3).

PART IV: CONCLUSIONS

34. The new concrete in all of the seven cores (MEM-5 CON-1, 3, 6, and 9 through 12) examined was intact and competent. The cracking present in the concrete did not appear to be a function of any deficiencies caused by constituents in the concrete. No frost damage to the concrete was observed in this nonair-entrained concrete.

35. The core of new concrete (MEM-5 CON-10) taken from monolith No. 60 contained minor amounts of alkali-silica reaction gel. This reaction was not considered to be a problem at this time. The adjacent concrete in this monolith, however, has severe map cracking and exudation which currently appears to be stable.[1]

36. The compressional wave velocities of the new concrete averaged 15,276 fps. Concretes with compressional wave velocities over 15,000 fps are usually considered to be of excellent quality.[5] This indication was verified by the compressive strength measurements which averaged 7630 psi.

37. No bond of old to new concrete was observed in the two horizontal cores which showed this contact (MEM-5 CON-5 and 7). Good contact was observed between old and new concrete at about 7-ft depth in the slant core (MEM-5 CON-9). The tie irons connecting the new and old concrete appear to be in good condition showing little or no rusting.

38. The old concrete was made up of several types of concrete. All of the concretes were similar physically and all were of a lower quality than the new concrete. The average compressive strength of the old concrete is 3,790 psi and the average compression wave velocity is 14,568 fps.

39. The maximum depth of deterioration was 3.0 ft in the old concrete core MEM-5 CON-8. This cracking of the concrete was not believed to be caused by alkali-silica reaction or frost action as was the case in other parts of the structure. Cores MEM-5 CON-4 and 7 of old concrete were showing signs of advanced weathering due to frost action and alkali-silica reaction which will result in eventual loss of surface concrete integrity.

40. The density was similar for the new as well as the old concrete. The density of the old concrete was slightly greater, probably due to the higher gravity limestone coarse aggregate in the old concrete. The similar densities suggest that the amount of coal present in the concretes was not sufficiently different to significantly affect this property. Visual observations confirmed this conclusion.

41. The overall concrete condition is such that major rehabilitation of the floodwall does not appear necessary at this time. However, several localized areas appear to warrant repair. These include cracking around the metal plate waterstops between monoliths, isolated vertical cracks near the middle and approximately at the third points of some monoliths, and isolated areas of advanced concrete deterioration in the old wall.

42. The metal plate waterstops at those monolith joints where severe cracking has occurred should be removed and replaced with flexible waterstops. Either impact tools or diamond saws appear to be most feasible in removal of wall sections immediately surrounding the waterstops. Conventional forming and concrete placing procedures are recommended for rebuilding the monolith joints. Epoxy injection appears to be the most feasible method of repair for the isolated vertical cracks within the monoliths. In those areas of the old wall requiring repair, the deteriorated concrete should be removed down to sound concrete and replaced using conventional concrete forming and placing techniques.

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3. U. S. Army Engineer Waterways Experiment Station, CE, Handbook for Concrete and Cement, with quarterly supplements, Vicksburg, Miss., Aug 1949.
4. The Rock-Color Chart Committee, E. N. Goddard, Chairman, "Rock-Color Chart," 1975, The Geological Society of America, Boulder, Colo.
5. Malhotra, V. M., Testing Concrete: Nondestructive Methods, ACI Monograph No. 9, American Concrete Institute, Detroit, Mich., 1976.

Table 1

Caruthersville Core Locations and Identification

SL Serial No.	Field Serial No.	Description		
		Monolith	Station	Section
MEM-5 CON-1	CF-83-1	7	27/4865.5	New concrete (A)
MEM-5 CON-2	CF-83-2	17	27/5166.7	Old concrete (A)
MEM-5 CON-3	CF-83-3	17	27/5172.1	New concrete (A)
MEM-5 CON-4	CF-83-4	43	28/0847.7	Old concrete (B)
MEM-5 CON-5	CF-83-5	45	28/0896.7	Old concrete (B)
MEM-5 CON-6	CF-83-6	45	28/0901.7	New concrete (B)
MEM-5 CON-7	CF-83-7	47	28/0960.3	Old concrete (B)
MEM-5 CON-8	CF-83-8	53	28/1184.7	Old concrete (B)
MEM-5 CON-9	CF-83-9	53	28/1187.8	New concrete (B)
MEM-5 CON-10	CF-83-10	60	28/1381.5	New concrete (B)
MEM-5 CON-11	CF-83-11	74	28/1890.2	New concrete (C)
MEM-5 CON-12	CF-83-12	87	28/2404.2	New concrete (D)

Table 2

Physical Data for Caruthersville Floodwall Old Concrete

Specimen (MEM-5)	Depth, ft	p-Wave, ft/sec	Compressive Strength, psi	Density, lb/cu ft
CON-2	2.2-3.2	15,366	5790	150.5
	4.0-5.0	14,963	3440	150.1
CON-4	2.9-3.9	15,227	4270	150.2
	3.9-4.9	15,176	3720	150.0
CON-5	0.0-1.0	15,111	3310	150.9
CON-8	0.0-1.0	10,970	2020	145.1
	5.3-6.3	15,164	3960	148.1
	Average	14,568	3790	149.3

Table 3

Physical Data for Caruthersville Floodwall New Concrete

Specimen (MEM-5)	Depth, ft	p-Wave, ft/sec	Compressive Strength, psi	Density, lb/cu ft
CON-1	0.5-1.5	14,926	7,150	148.2
CON-3	0.0-1.0	15,012	7,080	148.5
CON-9	0.0-1.0	15,404	8,600	146.3
	6.0-7.0	15,239	10,680	150.3
CON-10	0.6-1.6	15,378	7,040	148.6
CON-11	0.2-1.2	15,024	6,140	148.9
CON-12	0.5-1.5	15,950	6,700	149.0
	Average	15,276	7,630	148.5

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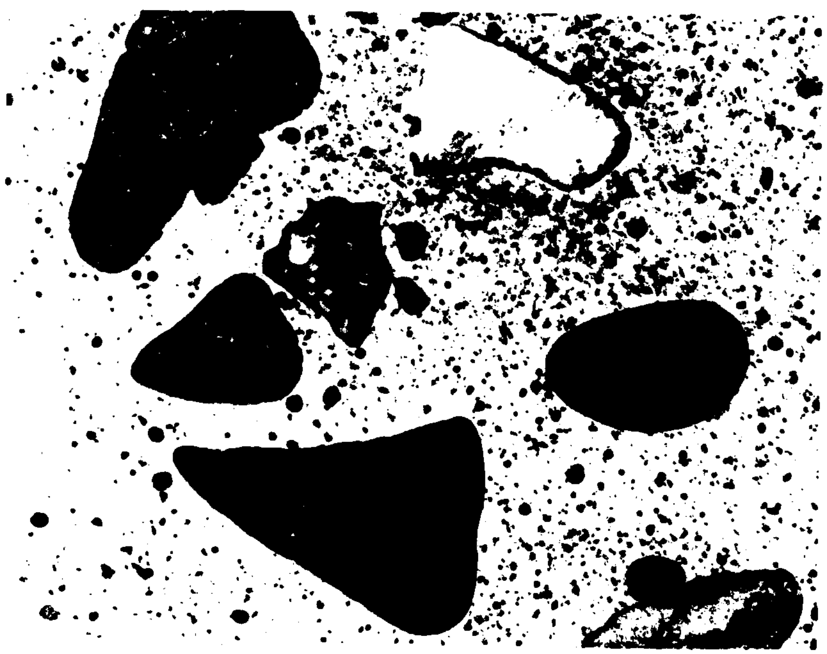
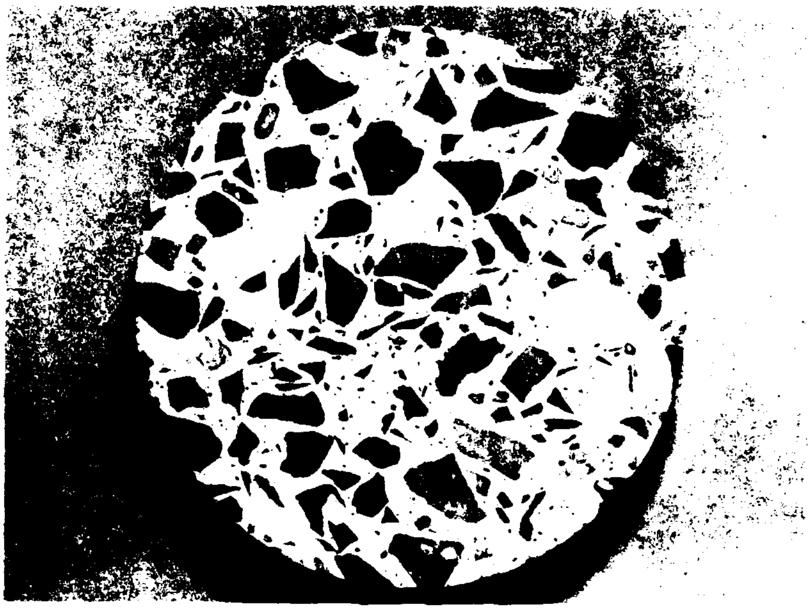


b. 2X

Photograph 1. Core MEM-5 CON-1 is concrete typical of the 1932 construction. No entrained air voids, oversanded and both gravel and sand appear gap graded



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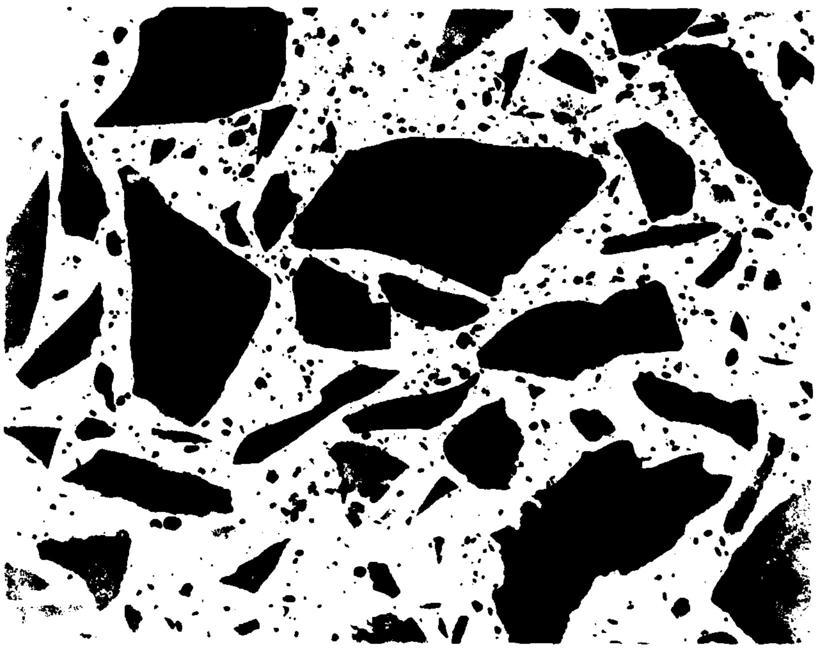
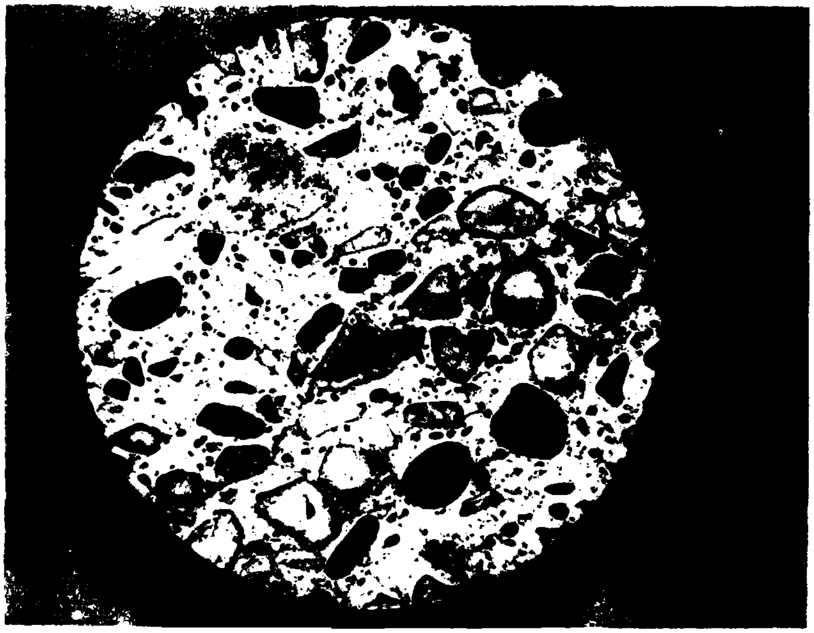


b. 2X

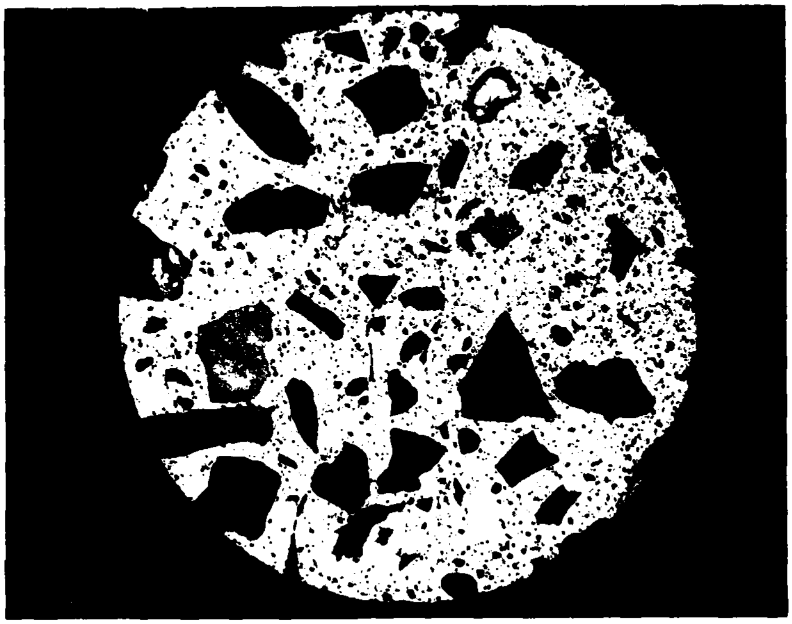
Photograph 2. Core MEM-5 CON-2 is typical of concrete in Type A section. Nonair-entrained concrete with crushed carbonate coarse aggregate and natural siliceous fine aggregate



a. 0.7X

b. 2X

Photograph 3. Core MEM-5 CON-7 is one of two types of concrete in Type B section. Nonair-entrained concrete with natural siliceous coarse and fine aggregate



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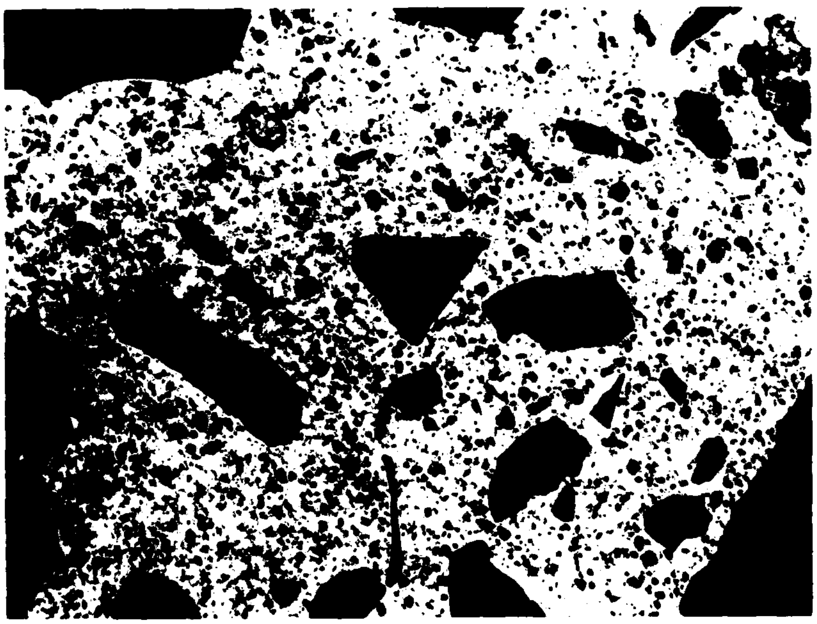


b. 2X

Photograph 4. Core MEM-5 CON-8 is one of two types of concrete in Type B section. Nonair-entrained concrete with crushed limestone coarse aggregate with occasional quartz gravel particle and a natural siliceous fine aggregate

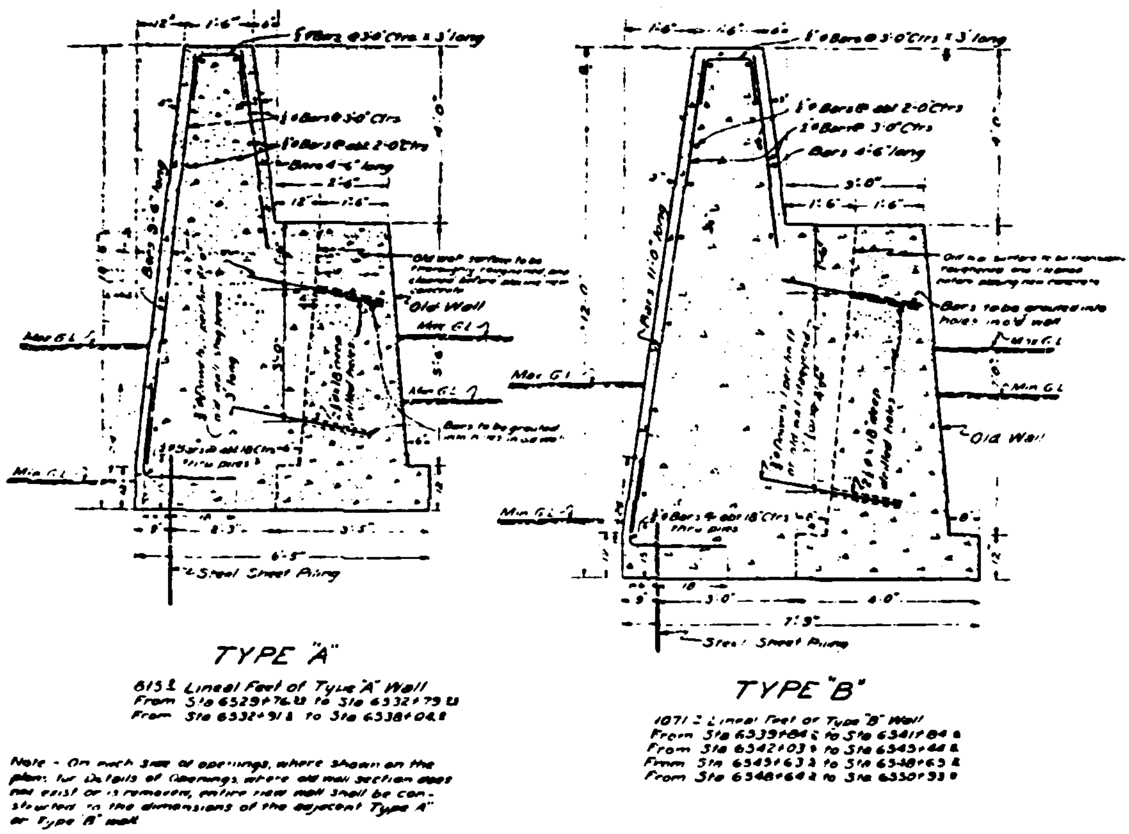


Figure 1. Typical wall sections incorporating an existing wall

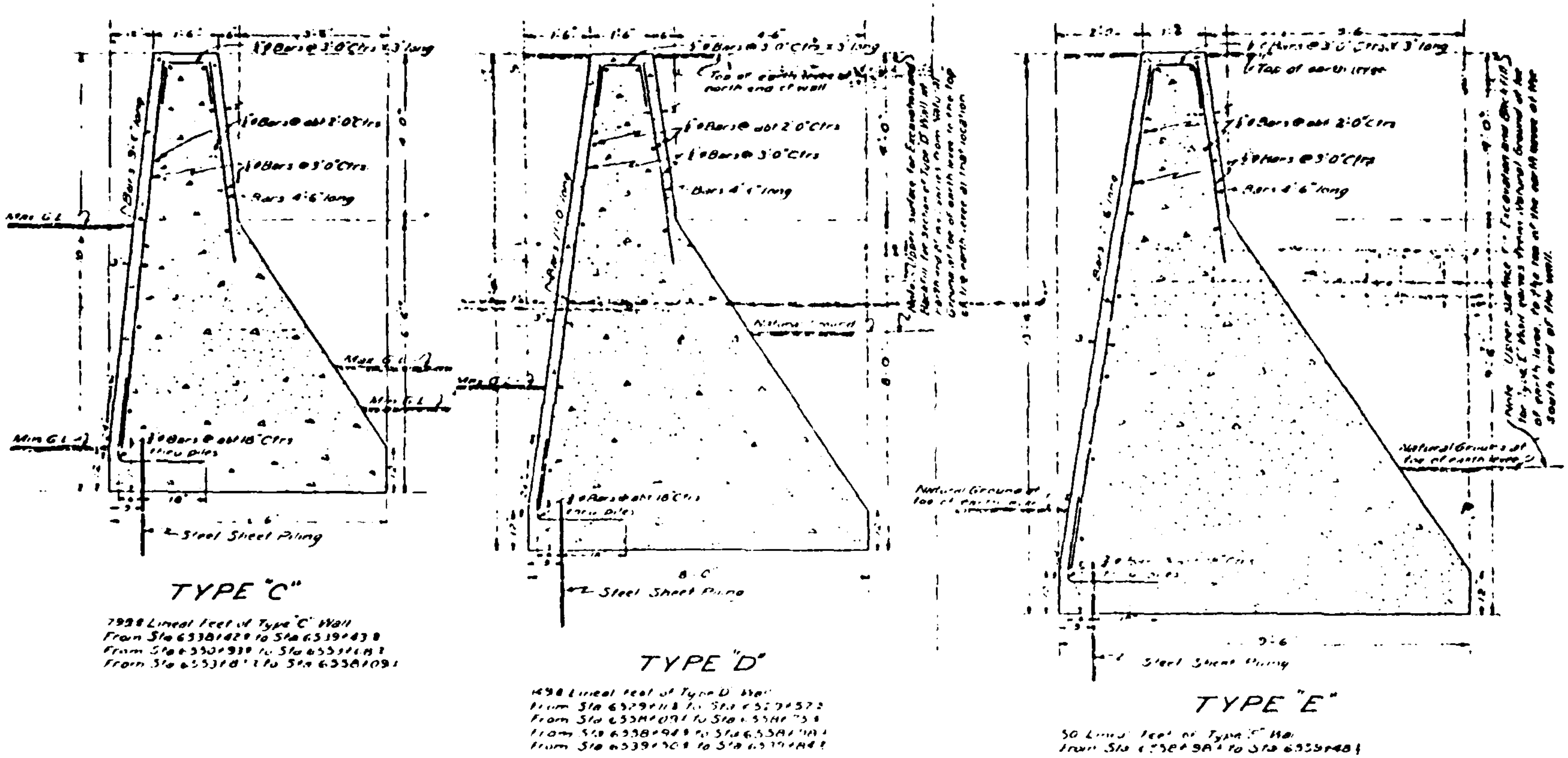
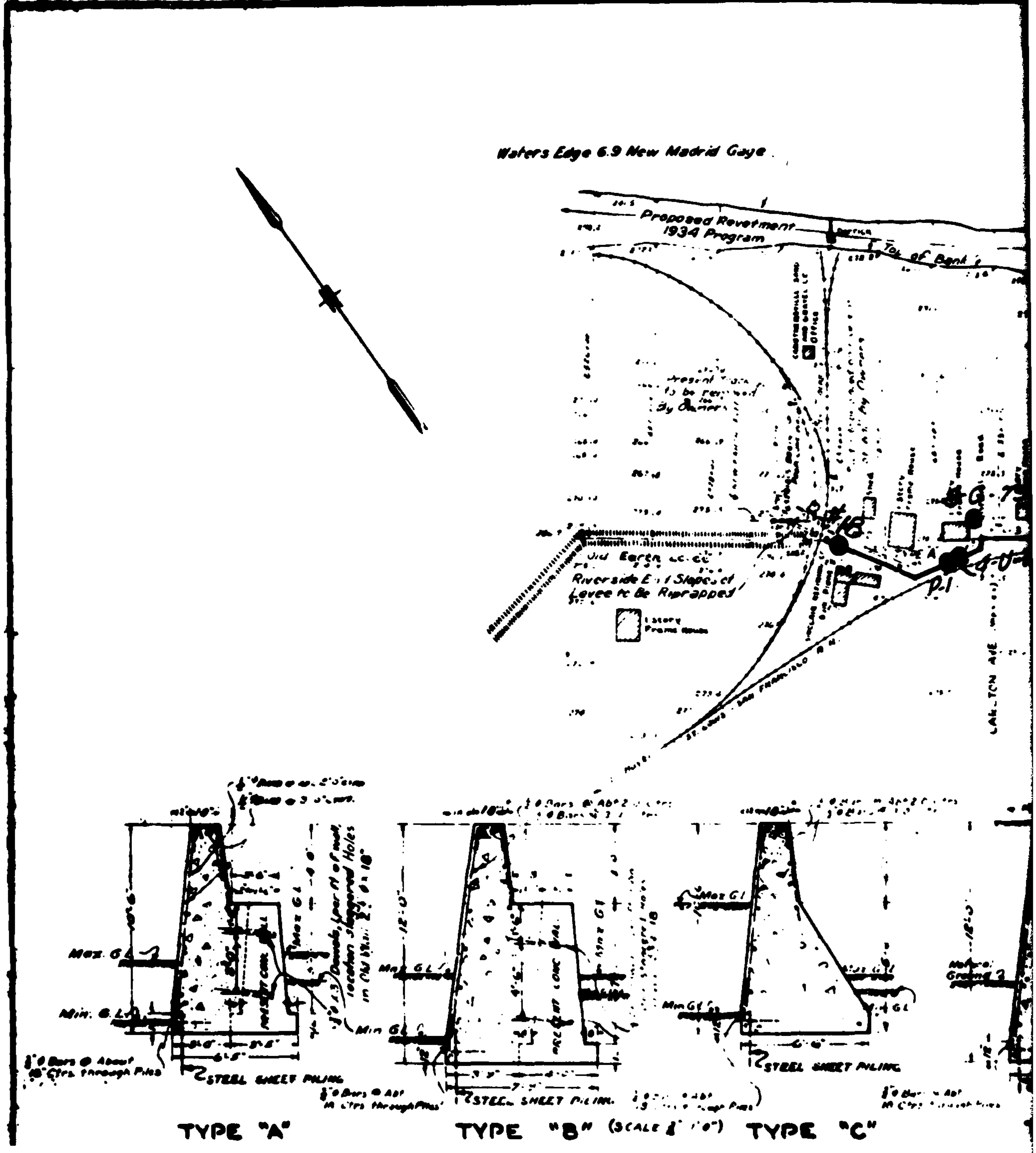
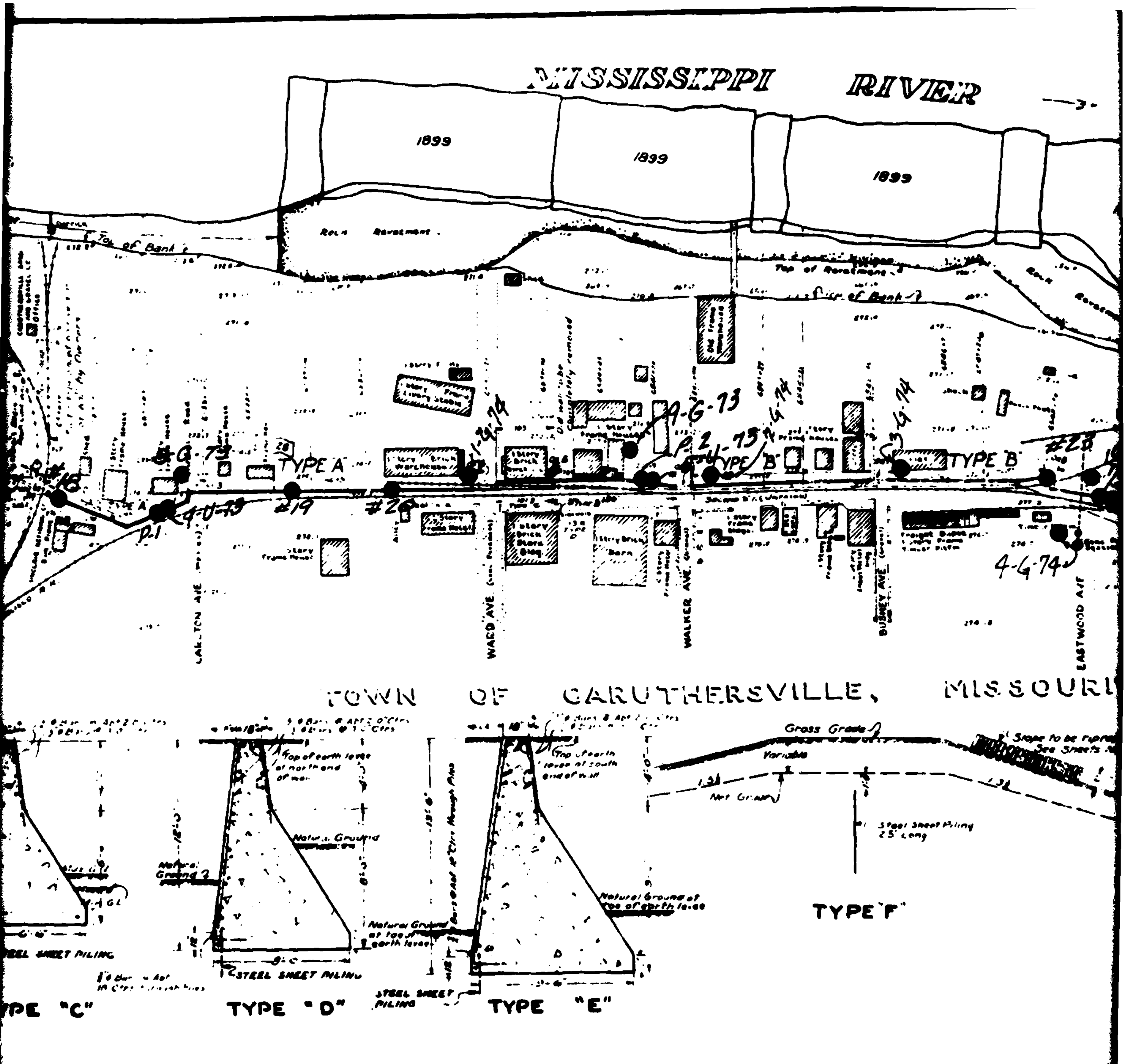


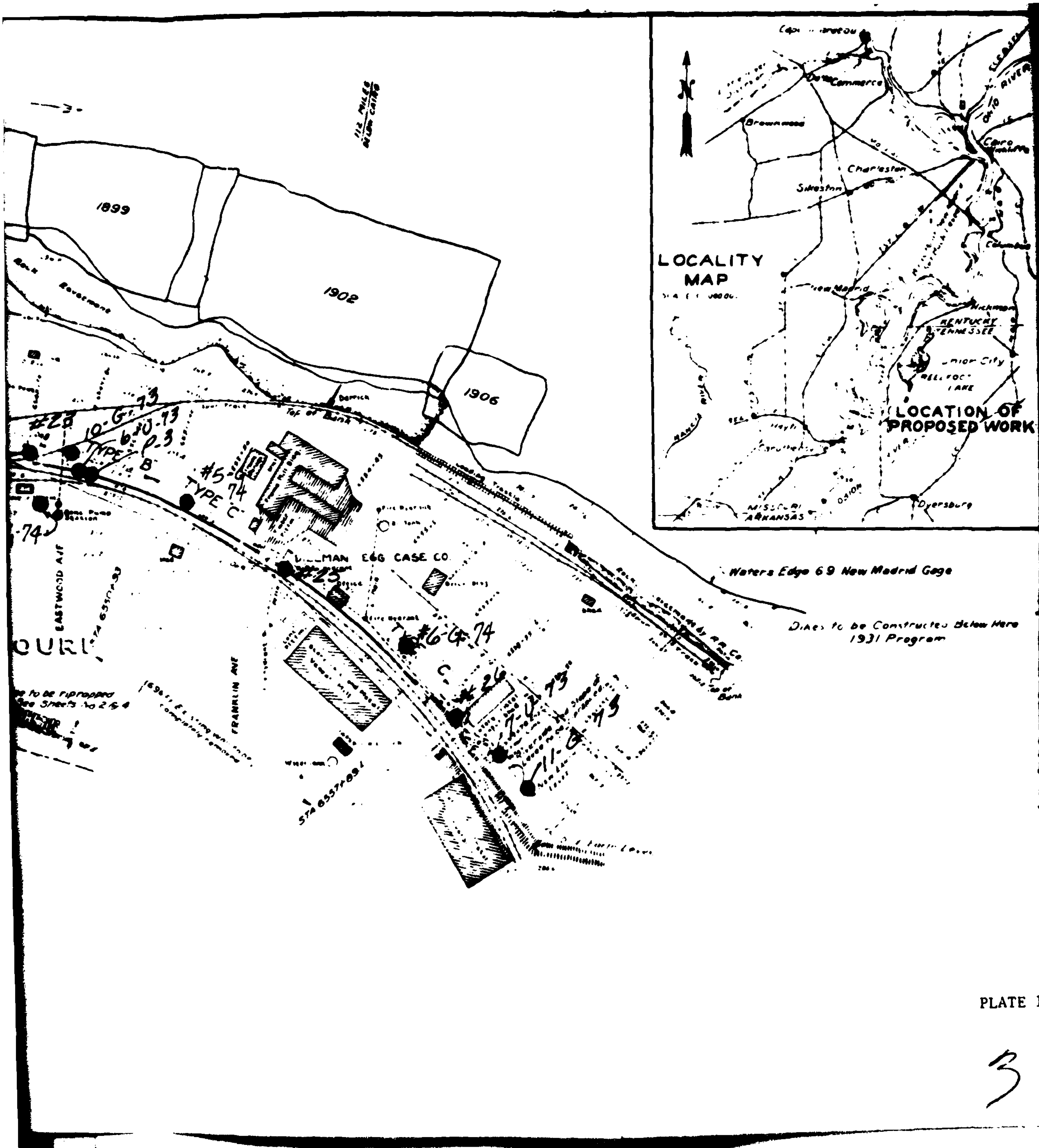
Figure 2. Typical wall sections, Types C-E

WAR DEPARTMENT




MISSISSIPPI RIVER
1899
1899
1899
Rock Revetment
Top of Bank
Top of Revetment
TYPE A
TYPE B
TYPE B
#19
#20
4-G-73
1-G-74
4-G-74
3-G-74
4-G-74
CARLTON AVE
WARD AVE
WALKER AVE
BUSHEY AVE
EASTWOOD AVE
TOWN OF CARUTHERSVILLE, MISSOURI
Gross Grade
Variable
Net Grade
Steel Sheet Piling 25' Long
TYPE "F"
Natural Ground
STEEL SHEET PILING
TYPE "C"
TYPE "D"
TYPE "E"

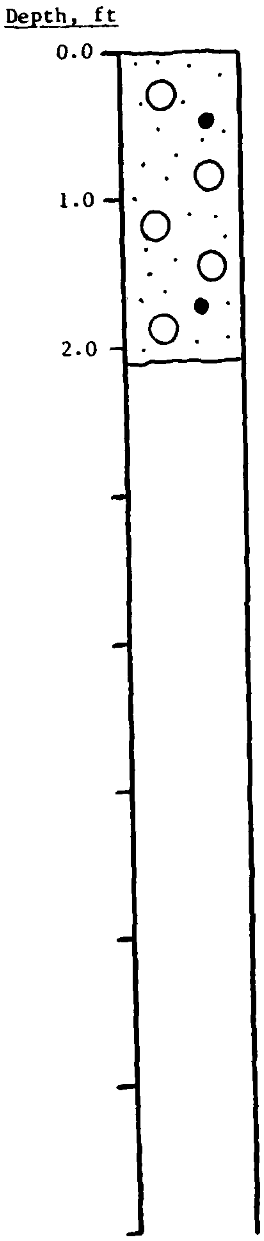
2



LOCALITY MAP
LOCATION OF PROPOSED WORK
Brownwood
Charleston
Sikeston
Commerce
New Madrid
KENTUCKY
TENNESSEE
Union City
Dyersburg
MISSOURI
ARKANSAS
1899
1902
1906
Top of Bank
Waters Edge 69 New Madrid Gage
Dikes to be Constructed Below Here
1931 Program
EGG CASE CO.
EASTWOOD AVE
FRANKLIN AVE
#5-G-74
TYPE C
#25
#6-G-74
10-G-73
6-U-73
P-3
TYPE B
11-G-73

PLATE 1

MEM-5 CON-1 (New concrete, horizontal boring),
Caruthersville Floodwall, Caruthersville, Missouri,
6-in.-diameter core



Finished surface (land side)

1/2-in. steel rebar

1/2-in. steel rebar

End of boring 2.1 ft   Finished surface (river side)

Not air entrained
1-1/2-in. maximum size natural aggregate
Mixed composition siliceous gravel
Gap graded coarse aggregate
Few coal particles
Natural siliceous sand
Good consolidation

MEM-5 CON-2 (Old concrete, vertical boring),
Caruthersville Floodwall, Caruthersville, Missouri,
6-in.-diameter core

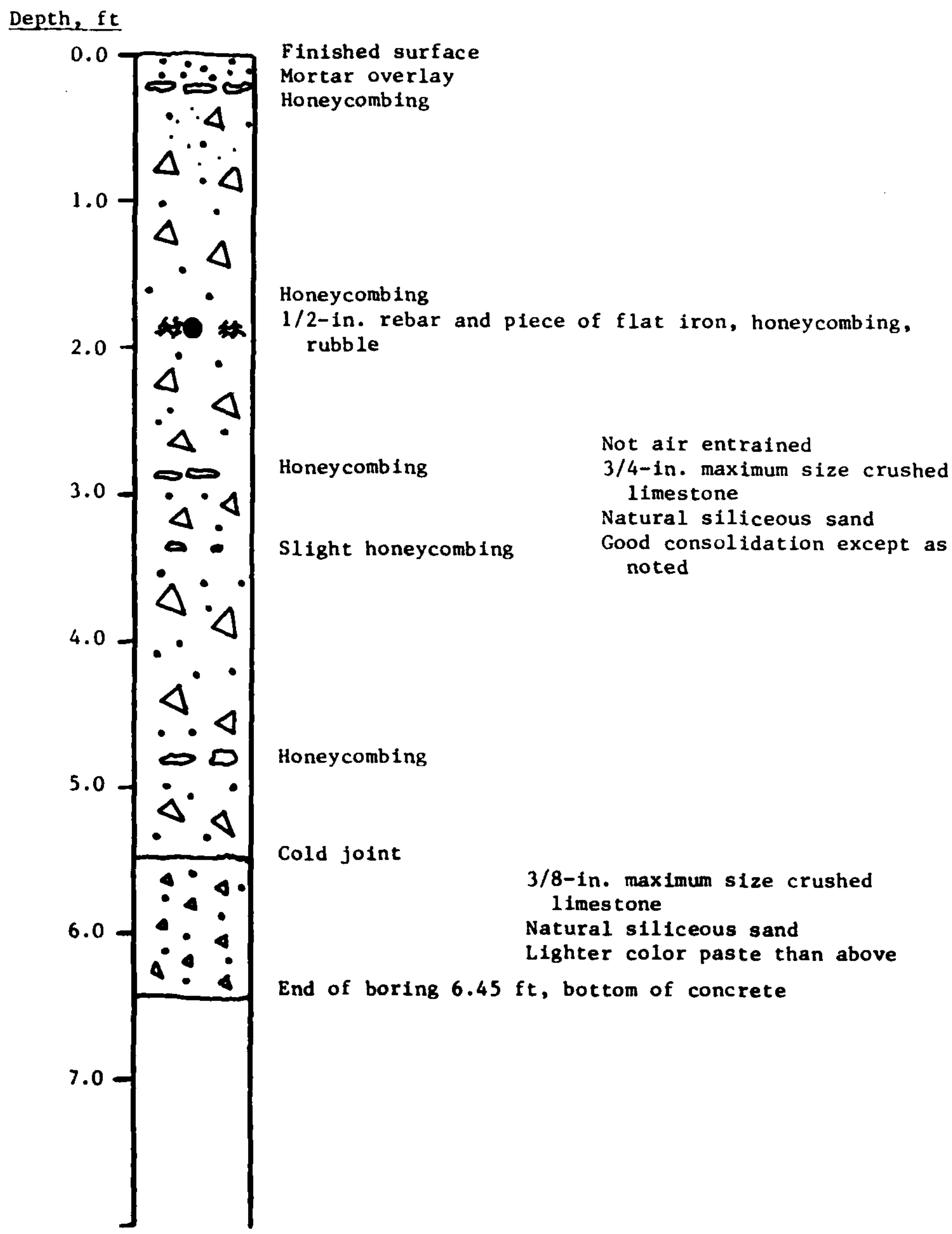
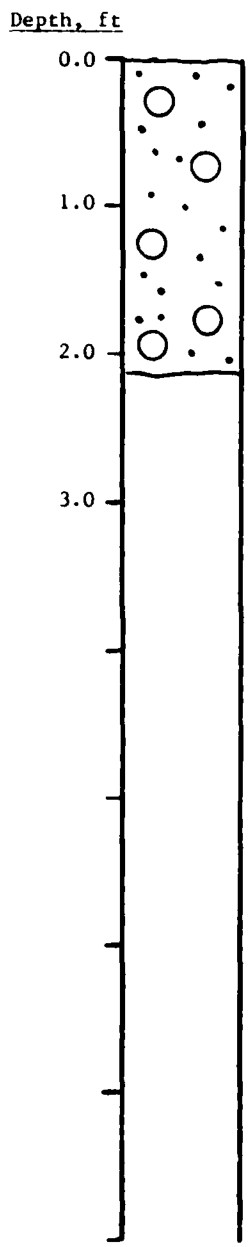


PLATE 3

MEM-5 CON-3 (New concrete, horizontal boring)
Caruthersville Floodwall, Caruthersville, Missouri,
6-in.-diameter core



Finished surface (land side)

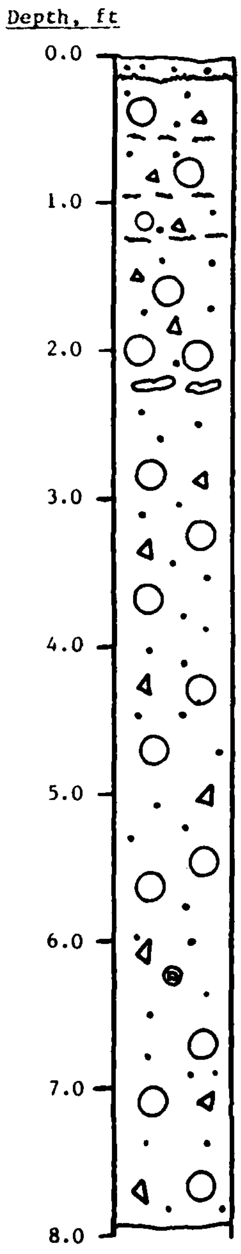
End of boring 2.1 ft

Finished surface (river side)

Not air entrained
1-1/2-in. maximum size natural aggregate
Mixed composition siliceous gravel
Gap graded coarse aggregate
Few coal particles
Natural siliceous sand
Good consolidation

Concrete is like MEM-5 CON-1

MEM-5 CON-4 (old concrete, vertical boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core



Finished surface
Mortar overlay
Pre-existing fracture between the overlay and the concrete

Honeycombing

Not air entrained
1-1/2-in. maximum size aggregate
Mostly 3/4-in. maximum size
Mixed composition siliceous gravel plus crushed limestone
Good consolidation except as noted

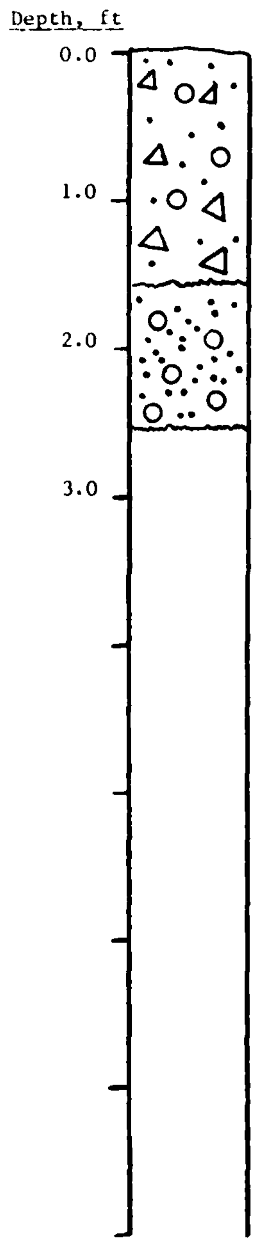
Flat iron, grouted

Poorly consolidated, honeycomb

End of boring 7.92 ft, bottom of concrete

PLATE 5

MEM-5 CON-5 (old and new concrete, horizontal boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core

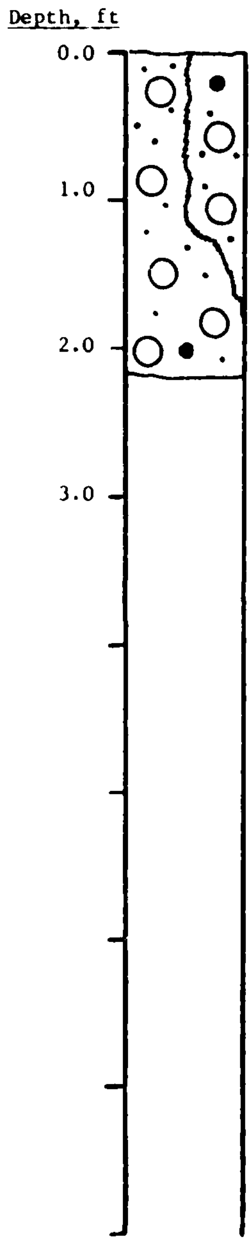


Slightly eroded formed surface (land side)
Old concrete
Not air entrained
3/4-in. maximum size crushed limestone with some siliceous particles
Gap graded
Natural siliceous sand
Some coal particles

Formed surface at interface
New concrete
Not air entrained
3/4-in. maximum size natural siliceous gravel generally 1/2 in. size or less; mostly mortar

End of boring 2.58 ft
Natural siliceous sand

MEM-5 CON-6 (New concrete, horizontal boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core



Finished surface (land side)
1/2-in. steel rebar

Not air entrained
1-1/2-in. maximum size aggregate
Mixed composition siliceous gravel
Few coal particles
Siliceous natural sand
Good consolidation

1/2-in. steel rebar
Finished surface (river side)

Major vertical crack from land wall side to river wall side (not all represented by this core); 1/2-in. rebar was perpendicular to crack surface and connected the concrete pieces.

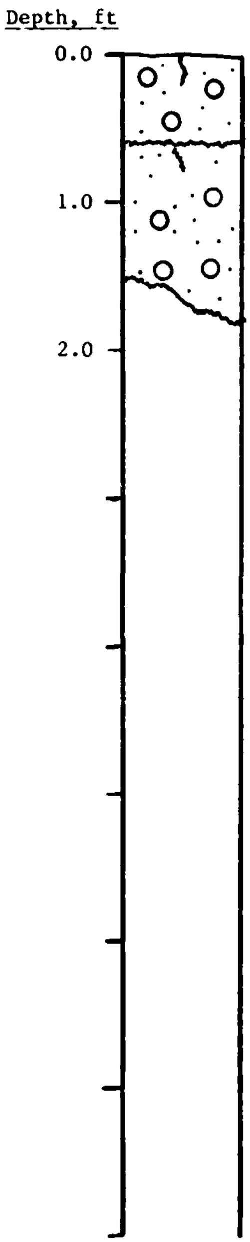
Crack surface stained by migrating water. Fractures went around aggregate and also through aggregate.

No alkali-aggregate reaction product found along crack.

Some alkali-silica reaction gel adjacent to crack.

PLATE 7

MEM-5 CON-7 (Old concrete, horizontal boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core



Slightly eroded surface (land side)

Not air entrained
1-1/2-in. maximum size aggregate; mostly 3/4-in. size
Mixed composition siliceous gravel
Mostly chert with quartz, sandstone, and some coal pieces
Siliceous natural sand

End of boring 1.8 ft at interface of old and new concrete

Concrete appears weathered and porous with some incipient longitudinal cracks as indicated.

Paste was light colored due to ettringite in voids and alkali-silica gel saturated mortar.

Paste was light gray (N7) to very light gray (N8)

MEM-5 CON-8 (Old concrete, vertical boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core

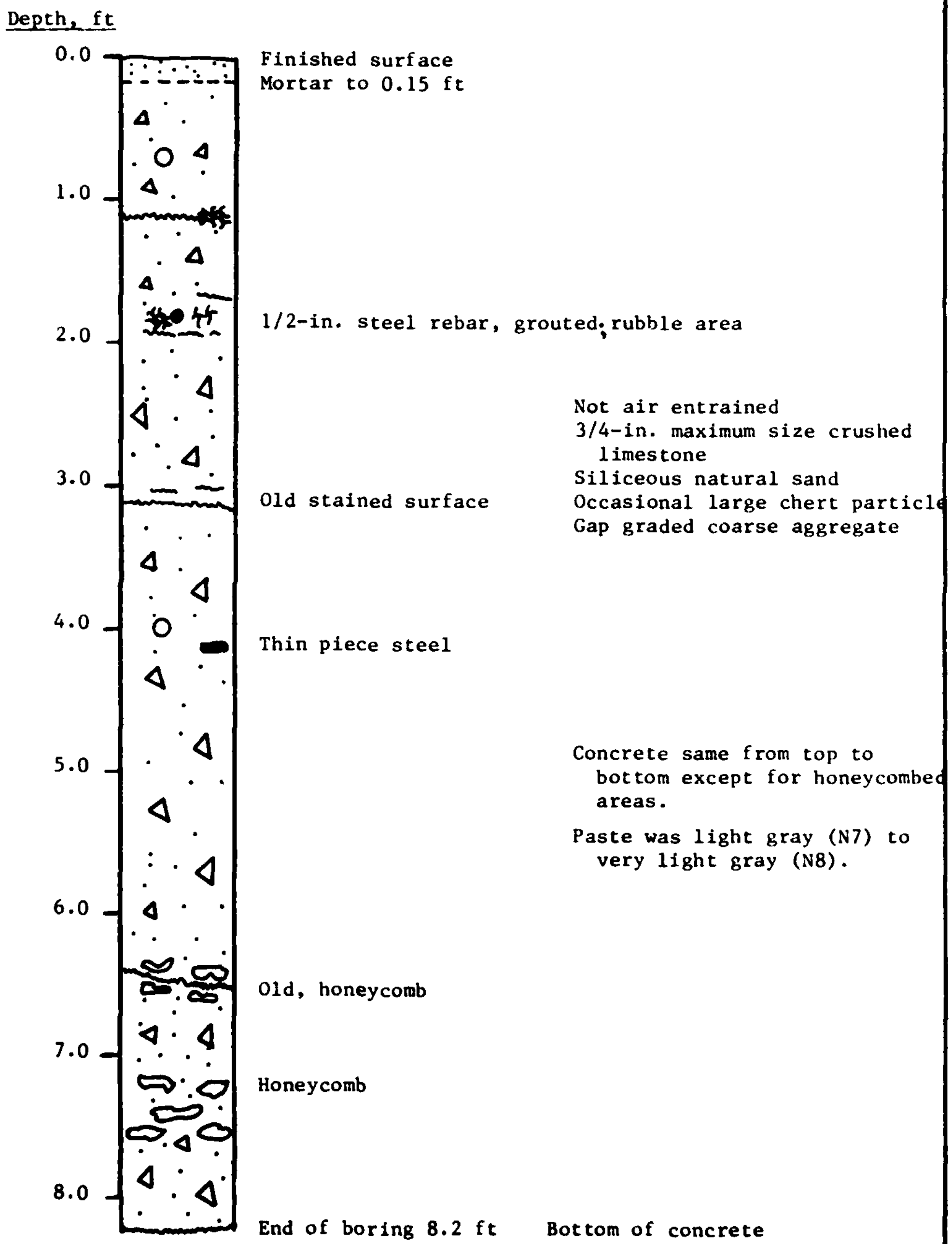
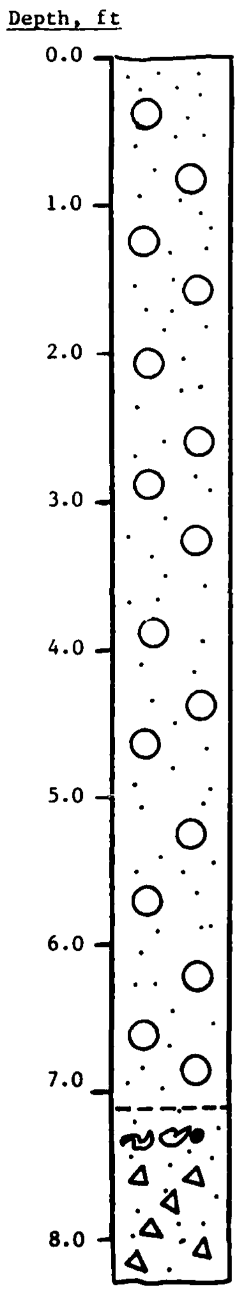


PLATE 9

MEM-5 CON-9 (New and old concrete, slant boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core



Finished surface

Not air entrained
1-1/2-in. maximum size aggregate; mostly mixed composition siliceous gravel

Siliceous natural sand

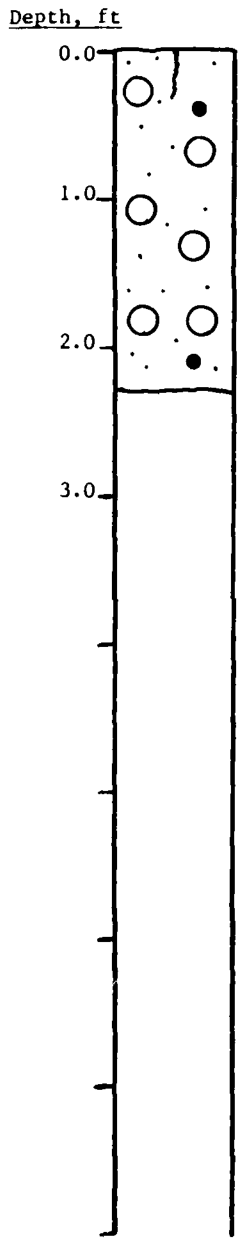
Concrete in good condition
No segregation
Good consolidation

Good contact with old concrete

1/2-in. steel rebar, honeycomb
Not air entrained
3/4-in. maximum size crushed limestone with a few siliceous particles

End of boring 8.32 ft

MEM-5 CON-10 (New concrete, horizontal boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core



Finished surface (land side)
Crack to 0.3-ft depth, stained

1/2-in. steel rebar

Not air entrained
1-1/2-in. maximum size aggregate
Mixed composition siliceous gravel
Some small pieces of coal
Siliceous natural sand

1/2-in. steel rebar
End of boring 2.3 ft   Finished surface (river side)

Some alkali-silica reaction gel at 1.9 ft associated with strained quartz particle.

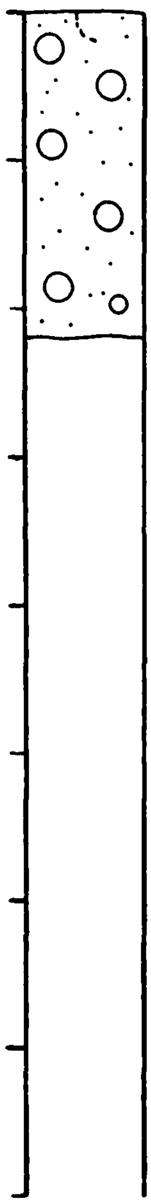
Some surface cracks on river side with no significant penetration.

Concrete appears in good condition.

MEM-5 CON-11 (New concrete, horizontal boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core

Depth, ft

0.0
1.0
2.0
3.0



Finished surface (river side)

Incipient fracture to 0.2 ft. Stained, crack around aggregate leaving ball and socket effect; no apparent reaction product.

Not air entrained

1-1/2-in. maximum size aggregate

Mixed composition siliceous gravel, quartz, chert, sandstone

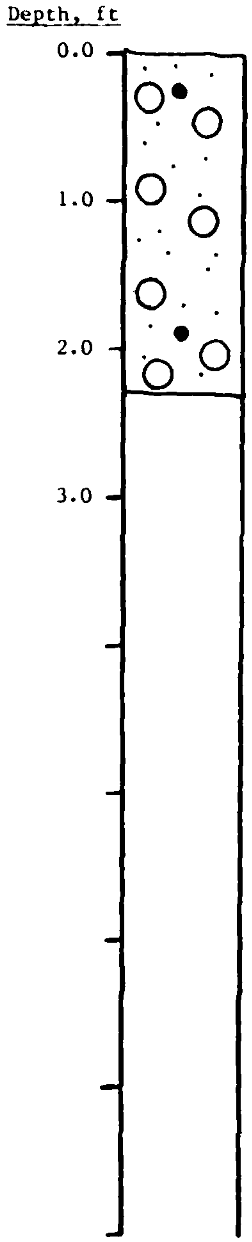
Some small pieces of coal

Siliceous natural sand

Finished surface (river side)

Paste was medium gray (N6) to light gray (N7).

MEM-5 CON-12 (New concrete, horizontal boring)
Caruthersville Floodwall, Caruthersville, Missouri
6-in.-diameter core



Finished surface (land side)
1/2-in. steel rebar

Not air entrained
1-1/2-in. maximum size aggregate
Mixed composition siliceous gravel, sandstone, gneiss, quartz, chert, miscellaneous igneous rocks
Some small pieces of coal
Siliceous natural sand

1/2-in. steel rebar

End of boring 2.3 ft, finished surface (river side)

Paste was light gray (N7) concrete in CON-12 similar to CON-11

END

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